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(54) **SYSTEM FOR ADDITIVELY MANUFACTURING COMPOSITE STRUCTURE**

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CPC ***B29C 64/393*** (2017.08); ***B22F 10/10*** (2021.01); ***B29C 64/106*** (2017.08);
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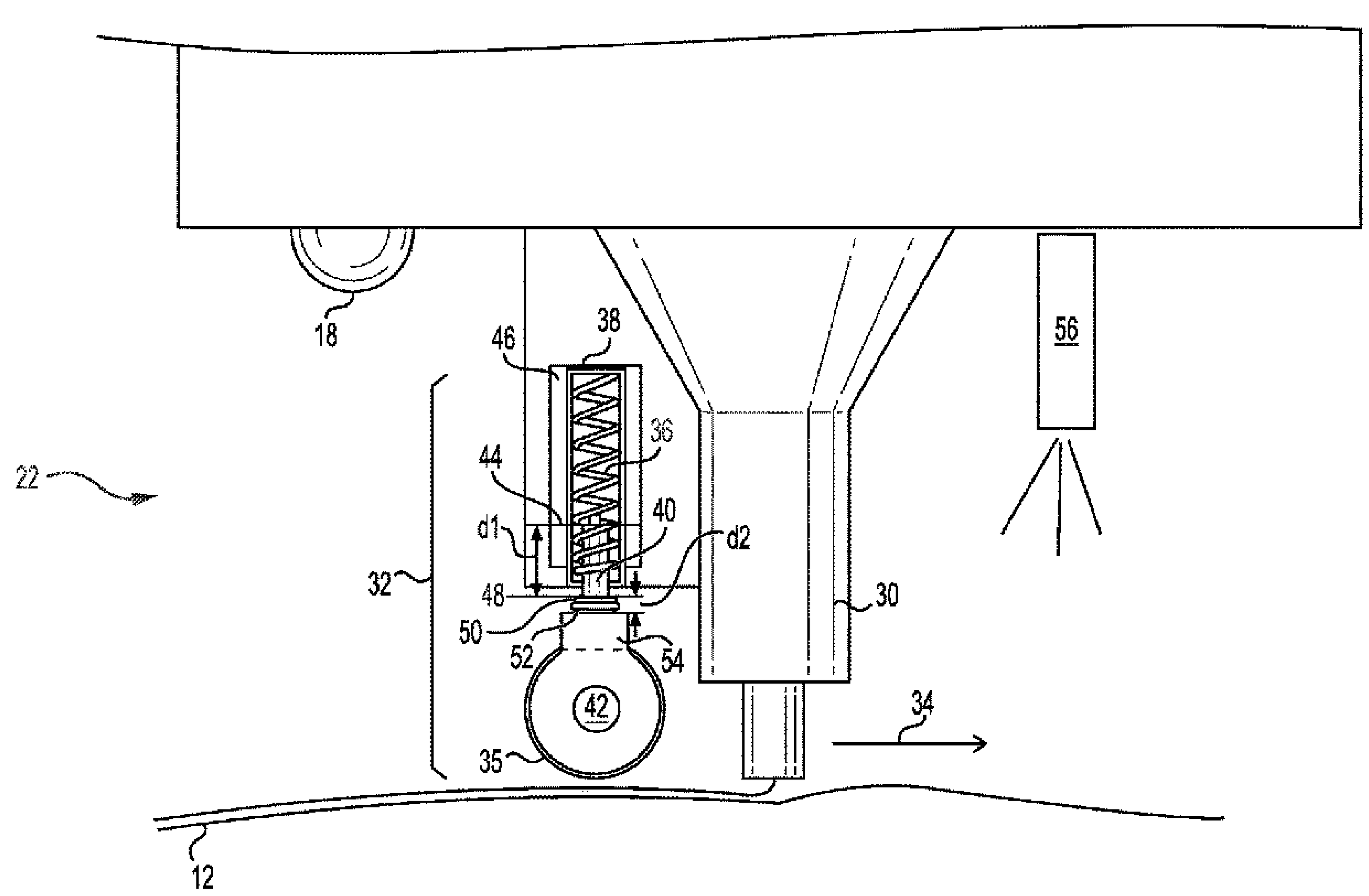
(57) **ABSTRACT**

A print head is disclosed for use in an additive manufacturing system. The print head may include an outlet configured to discharge a material, and a compacting device mounted to trail behind the outlet during movement of the print head in a normal direction. The print head may also include a spring configured to bias the compacting device against the material and to allow movement of the compacting device in a direction parallel with a discharge direction of the material through the outlet, and a locker configured to selectively lock a position of the compacting device relative to the outlet.

20 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

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(52) **U.S. Cl.**
CPC ***B29C 64/209*** (2017.08); ***B29C 64/218*** (2017.08); ***B29C 64/241*** (2017.08); ***B33Y 10/00*** (2014.12); ***B33Y 30/00*** (2014.12); ***B33Y 50/02*** (2014.12); *B29C 64/227* (2017.08); *B29C 64/232* (2017.08); *B29C 64/236* (2017.08); *B29C 64/379* (2017.08)

(58) **Field of Classification Search**
CPC B29C 64/194; B29C 64/218; B29C 70/38; B29C 70/384; B29C 70/524
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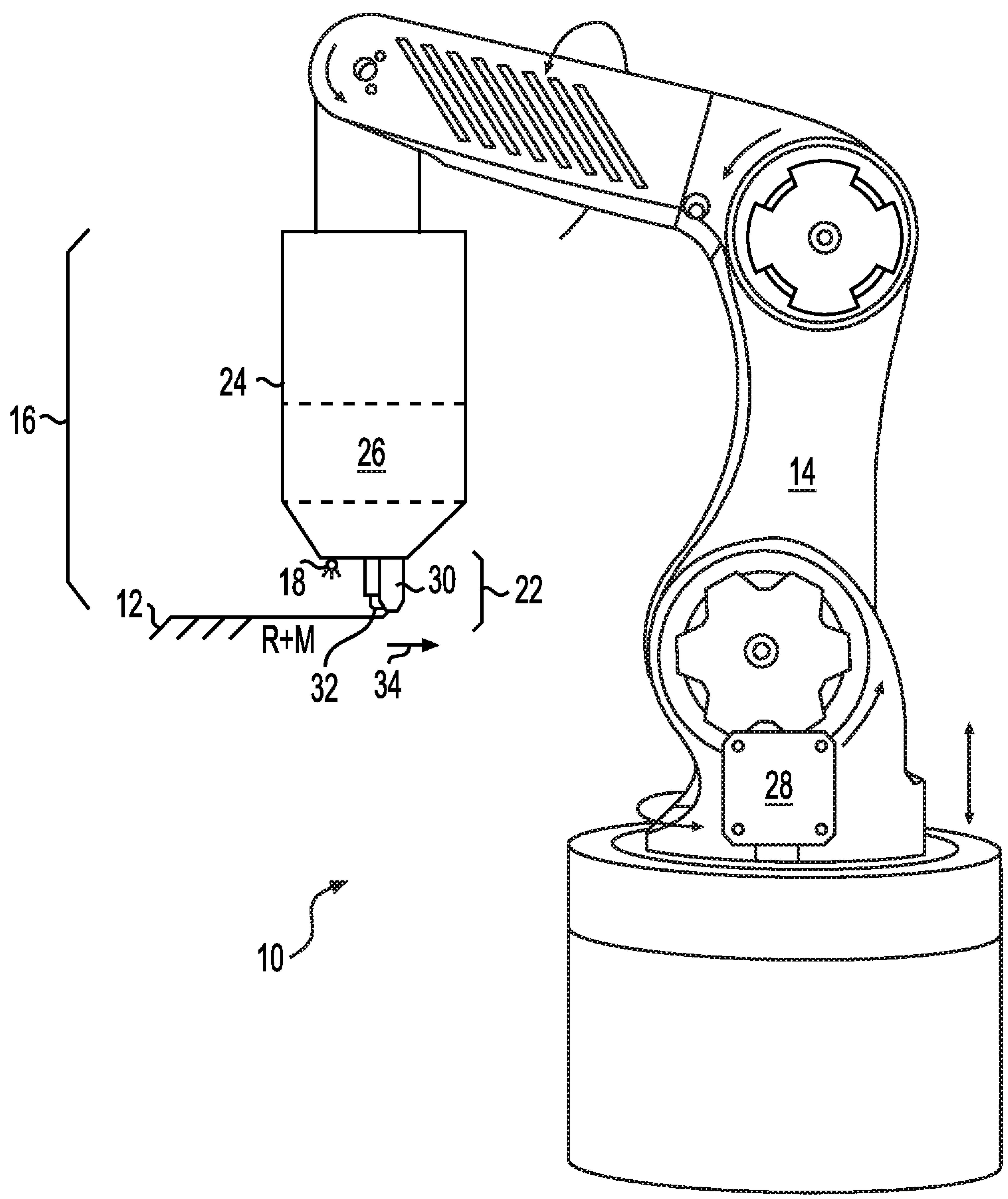

FIG. 1

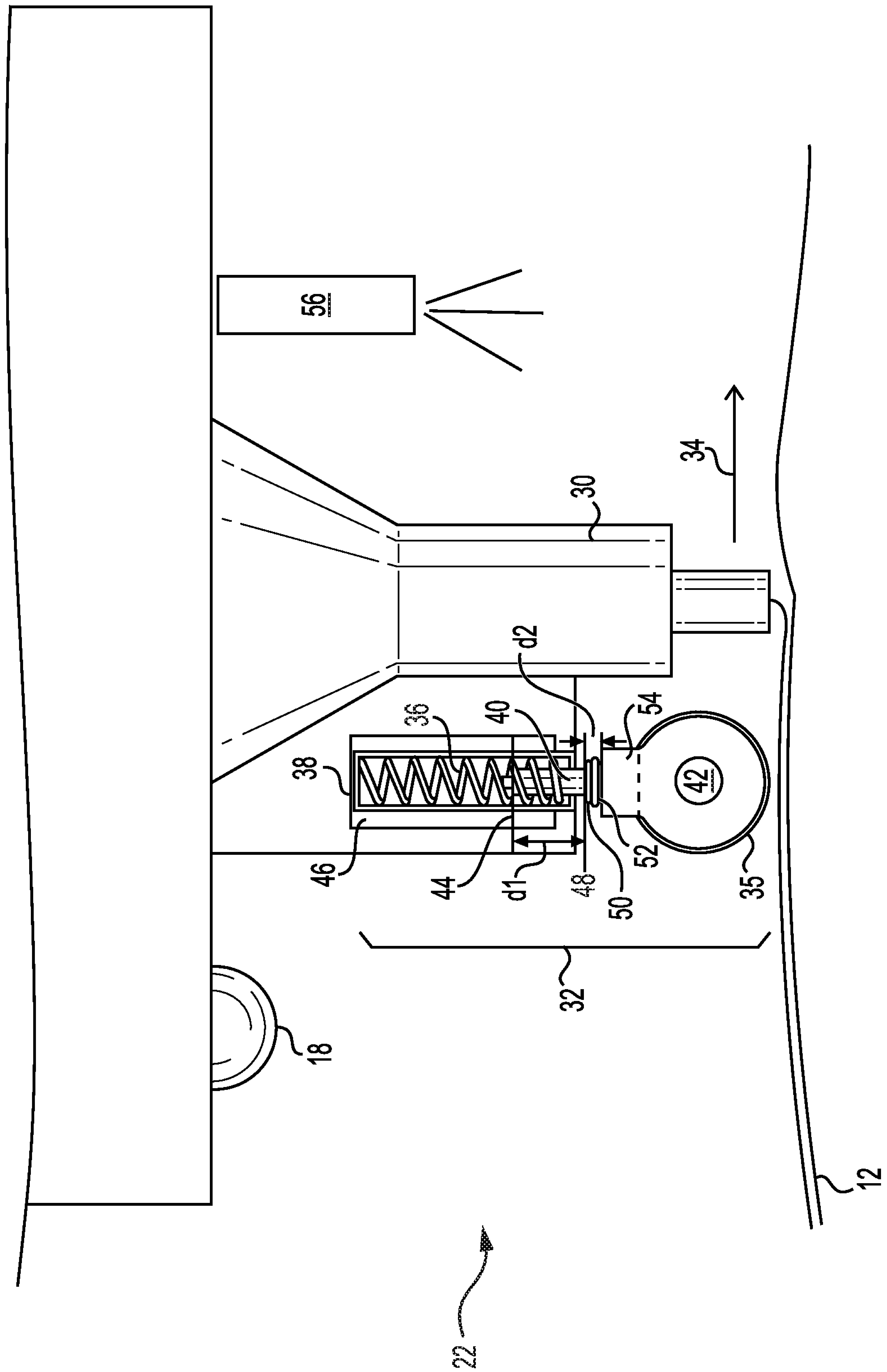

FIG. 2

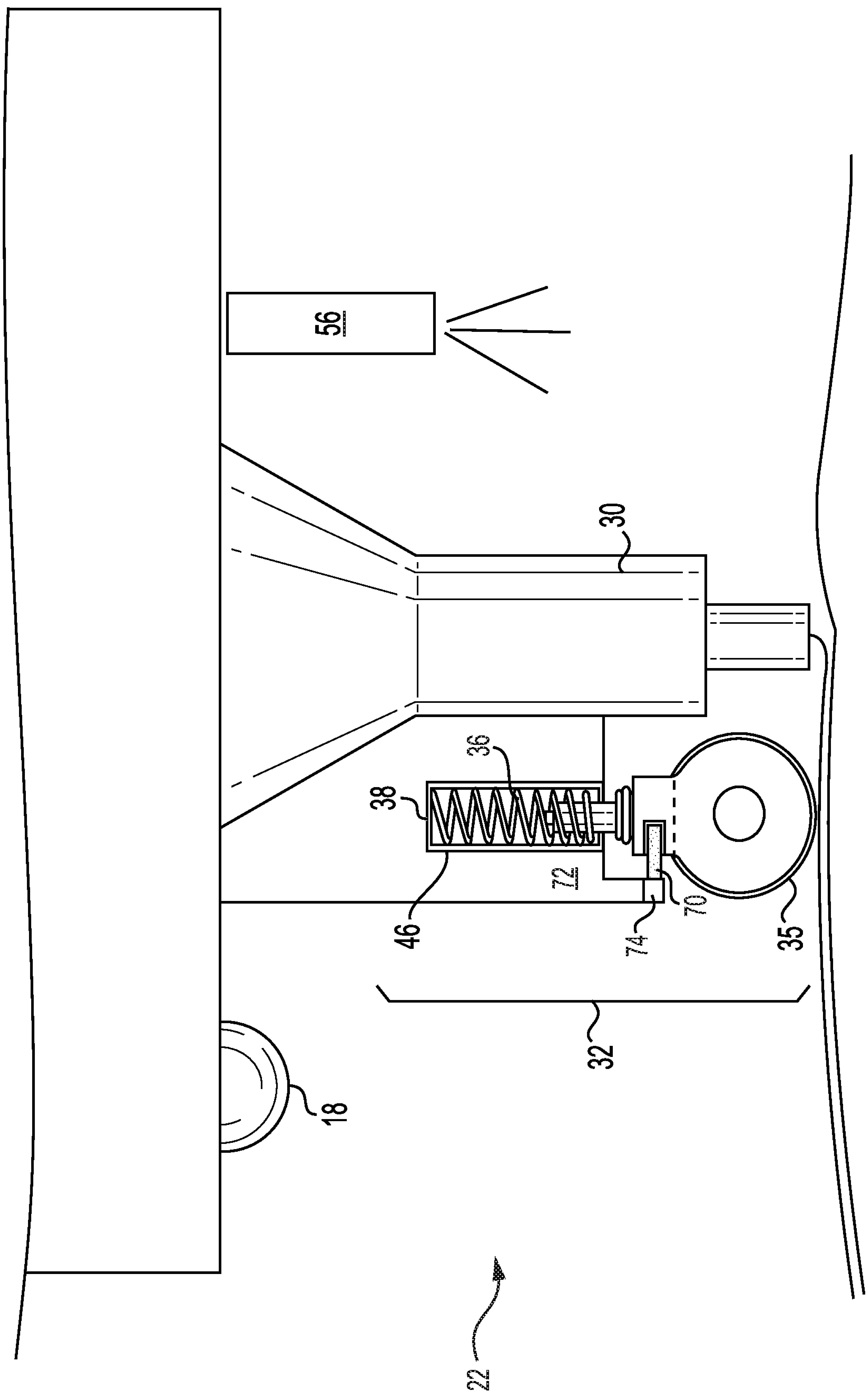

FIG. 3

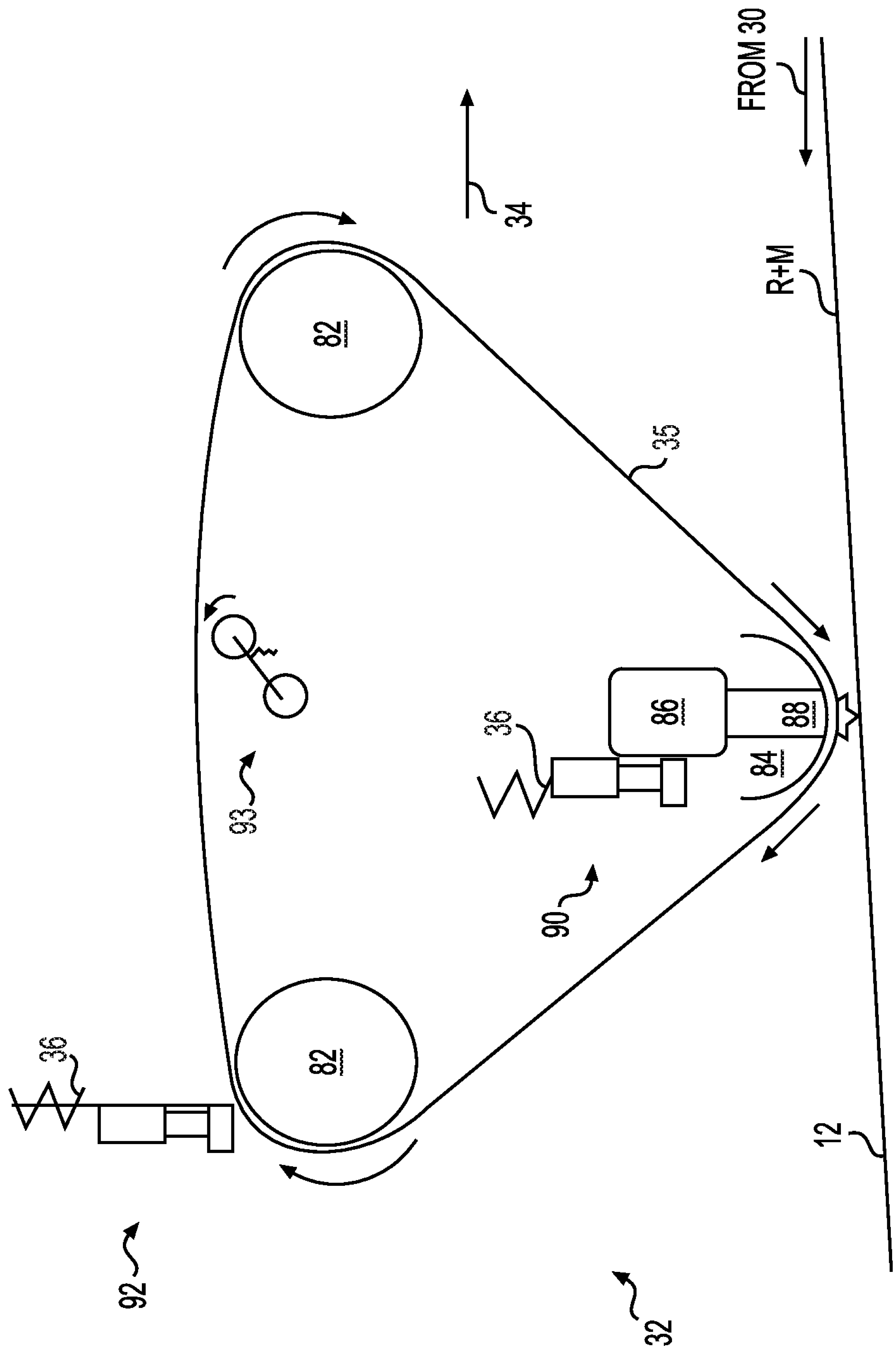

FIG. 4

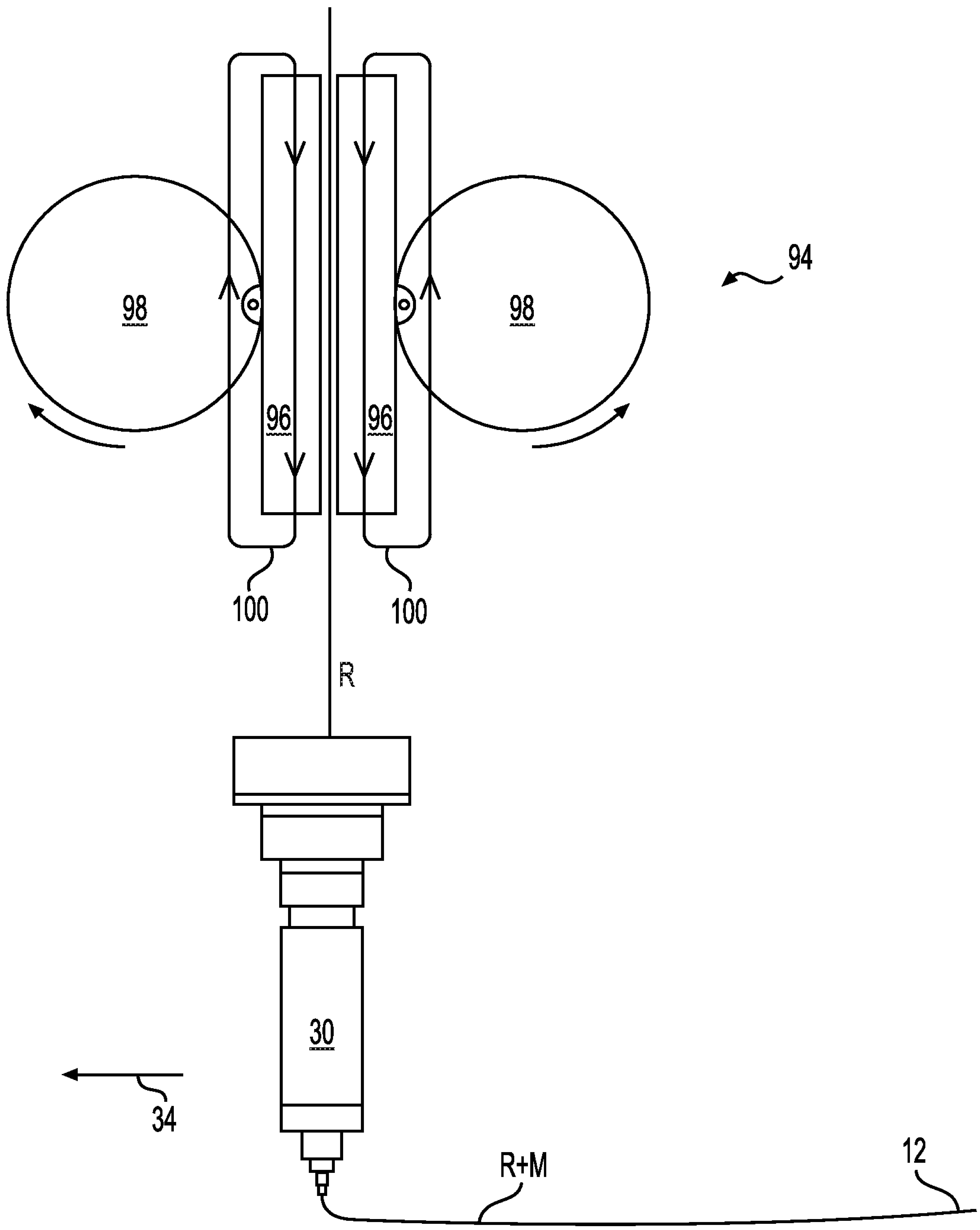

FIG. 5

SYSTEM FOR ADDITIVELY MANUFACTURING COMPOSITE STRUCTURE

RELATED APPLICATION

This application is based on and claims the benefit of priority from U.S. Provisional Application No. 62/853,610 that was filed on May 28, 2019, the contents of which are expressly incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates generally to a manufacturing system and, more particularly, to a system for additively manufacturing composite structures.

BACKGROUND

Continuous fiber 3D printing (a.k.a., CF3D®) involves the use of continuous fibers embedded within a matrix discharging from a moveable print head. The matrix can be a traditional thermoplastic, a powdered metal, a liquid resin (e.g., a UV curable and/or two-part resin), or a combination of any of these and other known matrixes. Upon exiting the print head, a head-mounted cure enhancer (e.g., a UV light, an ultrasonic emitter, a heat source, a catalyst supply, etc.) is activated to initiate and/or complete curing of the matrix. This curing occurs almost immediately, allowing for unsupported structures to be fabricated in free space. When fibers, particularly continuous fibers, are embedded within the structure, a strength of the structure may be multiplied beyond the matrix-dependent strength. An example of this technology is disclosed in U.S. Pat. No. 9,511,543 that issued to Tyler on Dec. 6, 2016 ("the '543 patent").

Although CF3D® provides for increased strength, compared to manufacturing processes that do not utilize continuous fiber reinforcement, improvements can be made to the structure and/or operation of existing systems. For example, Applicant has found that greater control over compacting and curing of the reinforcement can improve reinforcement placement, strength, and accuracy. The disclosed additive manufacturing system is uniquely configured to provide these improvements and/or to address other issues of the prior art.

SUMMARY

In one aspect, the present disclosure is directed to a print head for an additive manufacturing system. The print head may include an outlet configured to discharge a material, and a compacting device mounted to trail behind the outlet during movement of the print head in a normal direction. The print head may also include a spring configured to bias the compacting device against the material and to allow movement of the compacting device in a direction parallel with a discharge direction of the material through the outlet, and a locker configured to selectively lock a position of the compacting device relative to the outlet.

In another aspect, the present disclosure is directed to another print head for an additive manufacturing system. This print head may include an outlet configured to discharge a material, and paddles disposed upstream of the outlet and located at opposing sides of the material. The print head may also include at least one actuator pivotally connected to the paddles.

In yet another aspect, the present disclosure is directed to another print head for an additive manufacturing system. This print head may include an outlet configured to discharge a material, and a compactor located at a trailing side of the outlet relative to a normal travel direction of the print head. The compactor may have at least one roller, a guide, and a source of cure energy. The compactor may further include a belt wrapped around the at least one roller and guide, the belt being at least partially transparent to the cure energy.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic illustration of an exemplary disclosed additive manufacturing system;

FIGS. **2** and **3** are diagrammatic illustrations of exemplary disclosed outlets that may each form a portion of the system of FIG. **1**;

FIG. **4** is a diagrammatic illustration of an exemplary disclosed compactor that may form a portion of the outlet of FIG. **2**; and

FIG. **5** is a diagrammatic illustration of an exemplary disclosed reinforcement feeder that may form a portion of the system of FIG. **1**.

DETAILED DESCRIPTION

FIG. **1** illustrates an exemplary system **10**, which may be used to manufacture a composite structure **12** having any desired shape. System **10** may include a support **14** and a deposition head ("head") **16**. Head **16** may be coupled to and moved by support **14**. In the disclosed embodiment of FIG. **1**, support **14** is a robotic arm capable of moving head **16** in multiple directions during fabrication of structure **12**. Support **14** may alternatively embody a gantry (e.g., an overhead-bridge gantry or a single-post gantry) or a hybrid gantry/arm also capable of moving head **16** in multiple directions during fabrication of structure **12**. Although support **14** is shown as being capable of 6-axis movements relative to structure **12**, it is contemplated that support **14** may be capable of moving head **16** in a different manner (e.g., along and/or around a greater or lesser number of axes). It is also contemplated that structure **12** could be associated with one more movement axis and configured to move independent of and/or in coordination with support **14**. In some embodiments, a drive may mechanically couple head **16** to support **14**, and include components that cooperate to move portions of and/or supply power or materials to head **16**.

Head **16** may be configured to receive or otherwise contain a matrix (shown as M). The matrix may include any types or combinations of materials (e.g., a liquid resin, such as a zero-volatile organic compound resin, a powdered metal, etc.) that are curable. Exemplary resins include thermosets, single- or multi-part epoxy resins, polyester resins, cationic epoxies, acrylated epoxies, urethanes, esters, thermoplastics, photopolymers, polyepoxides, thiols, alkenes, thiol-enes, and more. In one embodiment, the matrix inside head **16** may be pressurized (e.g., positively and/or negatively), for example by an external device (e.g., by an extruder, a pump, etc.—not shown) that is fluidly connected to head **16** via a corresponding conduit (not shown). In another embodiment, however, the pressure may be generated completely inside of head **16** by a similar type of device. In yet other embodiments, the matrix may be gravity-fed into and/or through head **16**. For example, the matrix may be fed into head **16**, and pushed or pulled out of head

16 along with one or more continuous reinforcements (shown as R). In some instances, the matrix inside head **16** may need to be kept cool and/or dark in order to inhibit premature curing or otherwise obtain a desired rate of curing after discharge. In other instances, the matrix may need to be kept warm and/or illuminated for similar reasons. In either situation, head **16** may be specially configured (e.g., insulated, temperature-controlled, shielded, etc.) to provide for these needs.

The matrix may be used to at least partially coat any number of continuous reinforcements (e.g., separate fibers, tows, rovings, socks, and/or sheets of continuous material) and, together with the reinforcements, make up a portion (e.g., a wall) of composite structure **12**. The reinforcements may be stored within or otherwise passed through head **16**. When multiple reinforcements are simultaneously used, the reinforcements may be of the same material composition and have the same sizing and cross-sectional shape (e.g., circular, square, rectangular, etc.), or a different material composition with different sizing and/or cross-sectional shapes. The reinforcements may include, for example, carbon fibers, vegetable fibers, wood fibers, mineral fibers, glass fibers, plastic fibers, metallic fibers, optical fibers (e.g., tubes), etc. It should be noted that the term “reinforcement” is meant to encompass both structural and non-structural (e.g., functional) types of continuous materials that are at least partially encased in the matrix discharging from head **16**.

The reinforcements may be at least partially coated with the matrix while the reinforcements are inside head **16**, while the reinforcements are being passed to head **16**, and/or while the reinforcements are discharging from head **16**. The matrix, dry (e.g., unimpregnated) reinforcements, and/or reinforcements that are already exposed to the matrix (e.g., pre-impregnated reinforcements) may be transported into head **16** in any manner apparent to one skilled in the art. In some embodiments, a filler material (e.g., chopped fibers, nano particles or tubes, etc.) and/or additives (e.g., thermal initiators, UV initiators, etc.) may be mixed with the matrix before and/or after the matrix coats the continuous reinforcements.

One or more cure enhancers (e.g., a UV light, an ultrasonic emitter, a laser, a heater, a catalyst dispenser, etc.) **18** may be mounted proximate (e.g., within, on, and/or adjacent) head **16** and configured to enhance a cure rate and/or quality of the matrix as it is discharged from head **16**. Cure enhancer **18** may be controlled to selectively expose portions of structure **12** to energy (e.g., UV light, electromagnetic radiation, vibrations, heat, a chemical catalyst, etc.) during material discharge and the formation of structure **12**. The energy may trigger a chemical reaction to occur within the matrix, increase a rate of the chemical reaction, sinter the matrix, harden the matrix, solidify the matrix, polymerize the matrix, or otherwise cause the matrix to cure as it discharges from head **16**. The amount of energy produced by cure enhancer **18** may be sufficient to cure the matrix before structure **12** axially grows more than a predetermined length away from head **16**. In one embodiment, structure **12** is at least partially (e.g., completely) cured before the axial growth length becomes equal to an external diameter of the matrix-coated reinforcement.

The matrix and/or reinforcement may be discharged together from head **16** via any number of different modes of operation. In a first example mode of operation, the matrix and/or reinforcement are extruded (e.g., pushed under pressure and/or mechanical force) from head **16** as head **16** is moved by support **14** to create features of structure **12**. In a second example mode of operation, at least the reinforcement is pulled from head **16**, such that a tensile stress is created in the reinforcement during discharge. In this second mode of operation, the matrix may cling to the reinforcement and thereby also be pulled from head **16** along with the reinforcement, and/or the matrix may be discharged from head **16** under pressure along with the pulled reinforcement. In the second mode of operation, where the reinforcement is being pulled from head **16**, the resulting tension in the reinforcement may increase a strength of structure **12** (e.g., by aligning the reinforcements, inhibiting buckling, equally loading the reinforcements, etc.) after curing of the matrix, while also allowing for a greater length of unsupported structure **12** to have a straighter trajectory. That is, the tension in the reinforcement remaining after curing of the matrix may act against the force of gravity (e.g., directly and/or indirectly by creating moments that oppose gravity) to provide support for structure **12**.

The reinforcement may be pulled from head **16** as a result of head **16** being moved by support **14** away from an anchor point (e.g., a print bed, an existing surface of structure **12**, a fixture, etc.). For example, at the start of structure formation, a length of matrix-impregnated reinforcement may be pulled and/or pushed from head **16**, deposited against the anchor point, and at least partially cured, such that the discharged material adheres (or is otherwise coupled) to the anchor point. Thereafter, head **16** may be moved away from the anchor point, and the relative movement may cause the reinforcement to be pulled from head **16**. As will be explained in more detail below, the movement of reinforcement through head **16** may be selectively assisted via one or more internal feed mechanisms, if desired. However, the discharge rate of reinforcement from head **16** may primarily be the result of relative movement between head **16** and the anchor point, such that tension is created within the reinforcement. As discussed above, the anchor point could be moved away from head **16** instead of or in addition to head **16** being moved away from the anchor point.

Head **16** may include, among other things, an outlet **22** and a matrix reservoir **24** located upstream of outlet **22**. In one example, outlet **22** is a single-channel outlet configured to discharge composite material having a generally circular, tubular, or rectangular cross-section. The configuration of head **16**, however, may allow outlet **22** to be swapped out for another outlet that simultaneously discharges multiple channels of composite material having the same or different shapes (e.g., a flat or sheet-like cross-section, a multi-track cross-section, etc.). Fibers, tubes, and/or other reinforcements may pass through matrix reservoir **24** (e.g., through one or more internal wetting mechanisms **26** located inside of reservoir **24**) and be wetted (e.g., at least partially coated, encased, and/or fully saturated) with matrix prior to discharge.

Outlet **22** may take different forms. In one example, a guide or nozzle **30** is located downstream of wetting mechanism **26**, and a compactor **32** trails nozzle **30** (e.g., relative to a normal travel direction of head **16** during material discharge, as represented by an arrow **34**). It is contemplated that either of nozzle **30** or compactor **32** may function as a tool center point (TCP) of head **16**, to affix the matrix-wetted reinforcement(s) at a desired location prior to and/or during curing when exposed to energy by cure enhancer(s) **18**. It is also contemplated that nozzle **30** and/or compactor **32** may be omitted, in some embodiments. Finally, it is contemplated that the TCP of head **16** may not necessarily be associated with nozzle **30** or compactor **32** and instead be a location of cure energy exposure that is separate from these locations. The TCP may also switch locations in some applications.

One or more controllers **28** may be provided and communicatively coupled with support **14** and head **16**. Each controller **28** may embody a single processor or multiple processors that are programmed and/or otherwise configured to control an operation of system **10**. Controller **28** may include one or more general or special purpose processors or microprocessors. Controller **28** may further include or be associated with a memory for storing data such as, for example, design limits, performance characteristics, operational instructions, tool paths, and corresponding parameters of each component of system **10**. Various other known circuits may be associated with controller **28**, including power supply circuitry, signal-conditioning circuitry, solenoid driver circuitry, communication circuitry, and other appropriate circuitry. Moreover, controller **28** may be capable of communicating with other components of system **10** via wired and/or wireless transmission.

One or more maps may be stored within the memory of controller **28** and used during fabrication of structure **12**. Each of these maps may include a collection of data in the form of lookup tables, graphs, and/or equations. In the disclosed embodiment, the maps may be used by controller **28** to determine movements of head **16** required to produce desired geometry (e.g., size, shape, material composition, performance parameters, and/or contour) of structure **12**, and to regulate operation of cure enhancer(s) **18** and/or other related components in coordination with the movements.

An exemplary outlet **22** is illustrated in FIG. **2**. As shown in this figured, compactor **32** may include a compacting device (e.g., a wheel) **35** that is biased against the matrix-coated reinforcement (R+M) via a spring **36**. Spring **36** may be disposed within a housing **38** and configured to exert an axially extending force on compacting device **35** via one or more pistons **40** that protrude at least partially in housing **38**. In the disclosed embodiment, compacting device **35** is generally cylindrical and oriented orthogonally relative to a central axis of nozzle **30**, with one piston **40** located at each opposing end and extending parallel with the central axis. Each piston **40** may be connected to compacting device **35** via a corresponding bearing **42**.

In the disclosed embodiment, a movement of piston **40** (e.g., retracting into and/or extending out of housing **38**) may be limited. For example, a first limiter **44** may be positioned near an internal end of piston **40** and configured to slide in an axial direction of piston **40** within corresponding slots **46**. As piston **40** extends from housing **38**, limiter **44** may near closed ends of slots **46**, thereby inhibiting further extension. In another example, a second limiter **48** may be positioned around piston **40** at a location outside of housing **38**. As piston **40** retracts into housing **38**, limiter **48** may near an outer surface (e.g., a collar sized to receive piston **40** but block limiter **48**) of housing **38**, thereby inhibiting further retraction. It is contemplated that only one or both of first and second limiters **44**, **48** may be utilized at the same time in conjunction with compactor **32**, as desired. These limiters may allow compacting device **35** to extend through a range of distances in the Z-direction, thereby compacting most surfaces of the discharging material while at the same time maintaining an outer surface of structure **12** within an acceptable location zone. This location zone may help to reduce error buildup and provide structure **12** with tighter tolerances.

In some applications, it may be beneficial to selectively adjust the edge location and/or extension range of the location zone. For example, the zone may be adjusted in a Z-direction (e.g., the axial direction of nozzle **30**) relative to the discharge location of head **16**. Additionally or alternatively, the zone may be made thicker or thinner. This may allow for variable compaction of the discharging material and tolerance control at the same time.

To facilitate this functionality, the location of limiter **44** and/or **48** relative to each other and/or relative to compacting device **35** may be moveable. For example, an effective length of pistons **40** may be adjustable by way of a threaded connection **50** of pistons **40** with bearings **42**. Specifically, pistons **40** may be unscrewed from bearings **42** (from an associated bearing housing) or screwed in further at connection **50** to make a distance d_1 shorter or longer. Similarly, a position of limiter **48** relative to compacting device **35** and/or relative to limiter **44** may be adjustable by way of another threaded connection **52**, such that unscrewing or screwing in of limiter **48** at connection **52** may make a distance d_2 shorter or longer. These adjustments may be made manually or automatically (e.g., via an associated actuator, such as one or more optional motors **54**), as desired. It is contemplated that other types of actuators (e.g., hydraulic actuators, solenoids, etc.) may be used to automatically adjust d_1 and/or d_2, if desired.

In embodiments where the adjustment of d_1 and/or d_2 are implemented automatically, the changes may be based on actual surface characteristics of structure **12** (e.g., as discharged during a previous fabrication pass). These characteristics may be detected in real time, for example via one or more sensors (e.g., cameras, infrared sensors, acoustic sensors, etc.—not shown) **56** located at a leading side of nozzle **30** (e.g., opposite compactor **32**). Additionally or alternatively, the changes may be based on a fabrication plan for structure **12**. For example, based on a need to create a void within structure **12** (e.g., for placement of a fastener or generation of a conduit), the location zone may be temporarily extended in the Z-direction toward structure **12** and/or made thicker. In another example, at a known point of reinforcement overlap (e.g., an intersection or other protruding anomaly), the location zone may be temporarily retracted and/or thinned to maintain the protrusion or extended and/or thickened to reduce the protrusion.

It may be beneficial, in some applications, to selectively lock motion (e.g., axial motion, rotational motion, and/or all motion) of compactor **32** to the rest of outlet **22**. For example, when transitioning from compacting of an overlapping layer to printing in free-space, it may be desirable to lock compacting device **35** at a fixed axial position relative to nozzle **30**, such that spring **36** does not suddenly extend compacting device **35** and cause a stepwise shift in the TCP location as compactor **32** is lifted away from the underlying layer. This locking may be accomplished, for example, by controller **28** reducing d_1 to zero.

FIG. **3** illustrates an alternative or additional way to axially lock compactor **32** at a fixed location. As shown in this figure, a separate and dedicated locker (e.g., a pin) **70** may be configured to mechanically fix compacting device **35** to the rest of outlet **22** (e.g., directly, or indirectly via a bracket **72**). Locker **70** may be moved (e.g., slid and/or rotated) from device **35** into a slot located within nozzle **30** and/or bracket **72** by way of an actuator **74** that is regulated by controller **28**. It is contemplated that a reverse action (e.g., movement of locker **70** into a slot formed within device **35**) may additionally or alternatively be implemented.

An alternative embodiment of compactor **32** is depicted in FIG. **4**. As shown in this figure, compacting device **35** may embody a belt that is at least partially transparent to cure energy. The belt may be wrapped around one or more rollers **82** (e.g., two, three, or four rollers **82**), which may or may not be driven, and a guide (e.g., a centrally located guide) **84**. Cure energy may be directed from a source **86** through a conduit **88** in guide **84** and through the transparent belt to expose and cure the matrix coating the reinforcement at an opposing side of the belt. Guide **84** may be a cylindrical, spherical, or other shaped roller, partial roller, or fixed sliding surface and located at the outlet of conduit **88** to help guide the belt past the outlet. It is contemplated that any number of guides **84** may be arranged adjacent each other across a width of the belt, if desired, for use in curing the matrix coating any number of adjacent reinforcements. A tensioner **93** may be associated with the belt of compactor **32** and positioned at any location (e.g., between rollers **82**) along its length, as desired.

Although compactor **32** is shown in FIG. **4** as having a general arrowhead shape, with a point of the arrow pointed towards the matrix-coated reinforcement, other orientations and/or shapes may also be possible. For example, the arrowhead shape could be inverted, such that a flat base side of the arrowhead rides along the matrix-coated reinforcement. In this embodiment, guide **84** could be located at a leading end of the flat side, at a trailing end, or at some point between the leading and trailing ends. In another example, additional rollers **82** may be utilized and placed adjacent guide **84** to form a generally rectangular or diamond shape.

In some embodiments, guides **84** may be individually position-adjustable (e.g., via one or more linear actuators **90**), such that a transverse shape of the belt may be manipulated. Similar to the embodiment of FIG. **2**, all of compactor **32** of FIG. **4** may also be adjustable in the Z-direction (e.g., via a linear and/or rotary actuator **92**), if desired.

Compactor **32** of FIG. **4** may be located at a fixed axial position relative to the rest of outlet **22** and/or be biased by spring **36** within a limited range of motion. For example, an additional spring **36** could be located to bias all of compactor **32** towards the matrix-coated reinforcement or to bias guide **84** relative to rollers **82**.

In some embodiments, an amount of back-tension within the reinforcement inside of head **16** may be too high (e.g., due to friction). High levels of tension can cause damage to the reinforcements and/or cause structure **12** to move undesirably during fabrication. For example, a newly discharged track of material can be pulled off structure **12**, if the tension is too high during curing. For these reasons, it can be important to reduce tension within head **16**. This can be facilitated with the use of one or more feed mechanisms placed anywhere upstream of a discharge location (e.g., nozzle **30**) of head **16** (e.g., inside of and/or upstream of head **16**).

Conventional feed mechanisms include opposing rollers that sandwich the reinforcement therebetween, wherein at least one of the rollers is driven to rotate by a motor. It has been found that conventional feed rollers can create high pressure along a line of contact between the opposing rollers. This high pressure can cause damage to the reinforcements and also press out too much matrix. In addition, reinforcements that have been wetted with matrix tend to stick to the rollers, causing jams within head **16**.

An exemplary feed mechanism **94** designed to address one or more of the issues of conventional feed rollers is illustrated in FIG. **5**. As can be seen in this figure, mechanism **94** may include tracks or paddles **96** located at opposing sides of the reinforcement, and one or more actuators **98** configured to move paddles **96** in a cyclical manner Paddles **96** may each include generally planar inner surfaces that are moved by actuators **98** to sandwich the reinforcement therebetween. Paddles **96** may be elongated in an axial direction of the reinforcement and have transverse widths that extend past the reinforcement at both opposing edges. An engagement area of paddles **96** may be selected to exert a desired pressure on the reinforcement that creates sufficient friction to advance the reinforcement in the axial direction without causing damage to the reinforcement. Actuators **98** may be rotary-type actuators (e.g., electric, pneumatic, and/or hydraulic motors) that each include a cam, pulley, or similar feature pivotally connected to paddles **96** at an outer periphery. Alternatively, actuators **98** may include linear actuators connected to paddles via a linkage arrangement (not shown). During operation of actuators **98**, paddles **96** may be caused to follow a circular, ellipsoidal, and/or rectangular trajectory (represented by arrows **100**). This trajectory may include a segment during which paddles **96** sandwich and advance the reinforcement, and a segment during which paddles **96** are separated from each other and resetting for a next advancement segment. Because paddles **96** separate from each other by movement away from the reinforcement in an orthogonal direction, the reinforcement may not wrap around and stick to any part of paddles **96**.

In some applications, compliance between paddles **96** may be helpful. For example, the compliance may provide a reliable level of pressure exerted by paddles **96** on the reinforcement therebetween. The compliance may be provided, for example, via a compliant material (e.g., foam, rubber, etc.) applied to the inner or engagement surfaces of paddles **96**. Alternatively or additionally, paddles **96** may be linked to the pivot connection points of actuators **98** via a spring that urges paddles **96** towards each other. Other configurations may also be possible.

INDUSTRIAL APPLICABILITY

The disclosed system may be used to manufacture composite structures having any desired cross-sectional shape and length. The composite structures may include any number of different fibers of the same or different types and of the same or different diameters, and any number of different matrixes of the same or different makeup. Operation of system **10** will now be described in detail.

At a start of a manufacturing event, information regarding a desired structure **12** may be loaded into system **10** (e.g., into controller **28** that is responsible for regulating operations of support **14** and/or head **16**). This information may include, among other things, a size (e.g., diameter, wall thickness, length, etc.), a contour (e.g., a trajectories, surface normal, etc.), surface features (e.g., ridge size, location, thickness, length; flange size, location, thickness, length; etc.), connection geometry (e.g., locations and sizes of couplings, tees, splices, etc.), reinforcement selection, matrix selection, discharge locations, curing specifications, compaction specifications, etc. It should be noted that this information may alternatively or additionally be loaded into system **10** at different times and/or continuously during the manufacturing event, if desired. Based on the component information, one or more different reinforcements and/or matrix materials may be installed and/or continuously supplied into system **10**.

To install the reinforcements, individual fibers, tows, and/or ribbons may be passed through matrix reservoir **24** and outlet **22** (e.g., through feed mechanism **94**, through features of nozzle **30**, and under compactor **32**). Installation of the matrix material may include filling head **16** (e.g., wetting mechanism **26** of reservoir **24**) and/or coupling of an extruder (not shown) to head **16**.

The component information may then be used to control operation of system **10**. For example, the in-situ wetted reinforcements may be pulled and/or pushed from outlet **22** of head **16** as support **14** selectively moves (e.g., based on known kinematics of support **14** and/or known geometry of structure **12**), such that the resulting structure **12** is fabricated as desired.

Operating parameters of support **14**, cure enhancer(s) **18**, compactor **32**, feed mechanism **94**, and/or other components of system **10** may be adjusted in real time during material discharge to provide for desired bonding, strength, tension, geometry, and other characteristics of structure **12**. Once structure **12** has grown to a desired length, structure **12** may be severed from system **10**. Feed mechanism **94** may thereafter be used to advance a start end of the reinforcement to the tool center or nip point of outlet **22**.

It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed system. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the disclosed system. It is intended that the specification and examples be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.

What is claimed is:

1. A print head for an additive manufacturing system, comprising:

an outlet configured to discharge a material;

a compacting module mounted to trail behind the outlet during movement of the print head, the

compacting module including a compacting device configured to compact the material;

a biasing device configured to bias the compacting device against the material and to allow translation of the compacting device in a direction towards and away from the material;

a locker configured to engage at least a portion of the compacting module to selectively lock translation of the compacting device; and

an actuator coupled to the locker, the actuator being configured to move the locker between a first position in which the locker mechanically engages with the at least a portion of the compacting module to selectively lock translation of the compacting device, and a second position in which is locker is mechanically disengaged with the at least the portion of the compacting module.

2. The print head of claim **1**, wherein:

the compacting device, when unlocked, has a range of motion; and

the range of motion is adjustable between non-zero ranges.

3. The print head of claim **2**, further including:

a first limiter configured to inhibit motion of the compacting device past a first end point away from the material; and

a second limiter configured to inhibit motion of the compacting device past a second end point toward the material,

wherein a location of at least one of the first and second limiters is adjustable.

4. The print head of claim **3**, wherein the location of each of the first and second limiters is adjustable.

5. The print head of claim **3**, further including an actuator configured cause adjustment of the at least one of the first and second limiters.

6. A print head for an additive manufacturing system, comprising:

an outlet configured to discharge a material;

a compacting device mounted to trail behind the outlet during movement of the print head in a normal direction;

a biasing device configured to bias the compacting device against the material and to allow movement of the compacting device in a direction towards and away from the material;

a locker configured to selectively lock a position of the compacting device; and

a controller programmed to automatically cause the locker to lock the position of the compacting device during transition between a first printing operation and a second printing operation.

7. The print head of claim **6**, wherein:

the first printing operation corresponds with printing of overlapping layers; and

the second printing operation corresponds with printing unsupported in free space.

8. The print head of claim **6**, further including a sensor configured to generate a signal indicative of a characteristic of the material after discharge and prior to compacting, wherein the controller is configured to selectively activate the locker based on the signal.

9. A print head for an additive manufacturing system, comprising:

an outlet configured to discharge a material;

a compacting device configured to compact the material after discharge;

a locker configured to mechanically engage the compacting device to lock a position of the compacting device relative to the material; and

a controller configured to cause the locker to lock the position of the compacting device during transition between a first printing operation and a second printing operation.

10. The print head of claim **9**, wherein the controller

is further configured to unlock the position of the compacting device during a start of a third printing operation.

11. The print head of claim **9**, wherein:

the first printing operation corresponds with printing of overlapping layers; and the second printing operation corresponds with printing unsupported in free space.

12. The print head of claim **9**, wherein the compacting device is moveable within a range during compaction of the material when the locker is unlocked.

13. The print head of claim **12**, wherein the compacting device is biased toward the material.

14. The print head of claim **9**, wherein the compacting device is biased toward the material.

15. The print head of claim **9**, further including:

a sensor configured to detect a characteristic of the material after discharge and prior to compaction; and the controller is configured to selectively activate the locker based on the sensor.

16. A print head for an additive manufacturing system, comprising:

an outlet configured to discharge a material;

a compacting device moveable within a range to compact the material after discharge;

an actuator including a device configured to mechanically engage with a portion of the compacting device, the actuator being configured to move the device between a first position in which the device mechanically engages with at least a portion of the compacting device to selectively lock translation of the compacting device, and a second position in which the device mechanically disengages with the at least the portion of the compacting device.

17. The print head of claim **16**, wherein the device is a locker configured to selectively lock the compacting device at a position within a range of positions.

18. The print head of claim **16**, further including a controller configured to activate the actuator during a transition between a first printing operation and a second printing operation.

19. The print head of claim **16**, wherein the compacting device is biased toward the material.

20. The print head of claim **16**, wherein the compacting device includes a roller, and the at least the portion of the compacting device is spaced apart from the roller.

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